JWST ISIM Harness Thermal Evaluation

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Abstract The James Webb Space Telescope (JWST) will be a large infrared telescope with a 6.5-meter primary mirror. Launch is planned for 2013. JWST will be the premier observatory of the next decade, serving thousands of astronomers worldwide. The Integrated Science Instrument Module (ISIM) is the unit that will house the four main JWST instruments. The ISIM enclosure is passively cooled to 37 Kelvin and has a tightly managed thermal budget. A significant portion of the ISIM heat load is due to parasitic heat gains from the instrument harnesses. These harnesses provide a thermal path from the Instrument Electronics Control (IEC) to the ISIM. Because of the impact of this load to the ISIM thermal design, understanding the harness parasitic heat gains is critical.

To this effect, a thermal test program has been conducted in order to characterize these parasitic loads and verify harness thermal models. Recent parasitic heat loads tests resulted in the addition of a dedicated multiple stage harness radiator. In order for the radiator to efficiently reject heat from the harness, effective thermal contact conductance values for multiple harnesses had to be determined. This presentation will describe the details and the results of this test program.

JWST ISIM Harness Thermal Evaluation

- The James Webb Space Telescope (JWST) will be a large infrared telescope with a 6.5-meter primary mirror. Launch is planned for 2013
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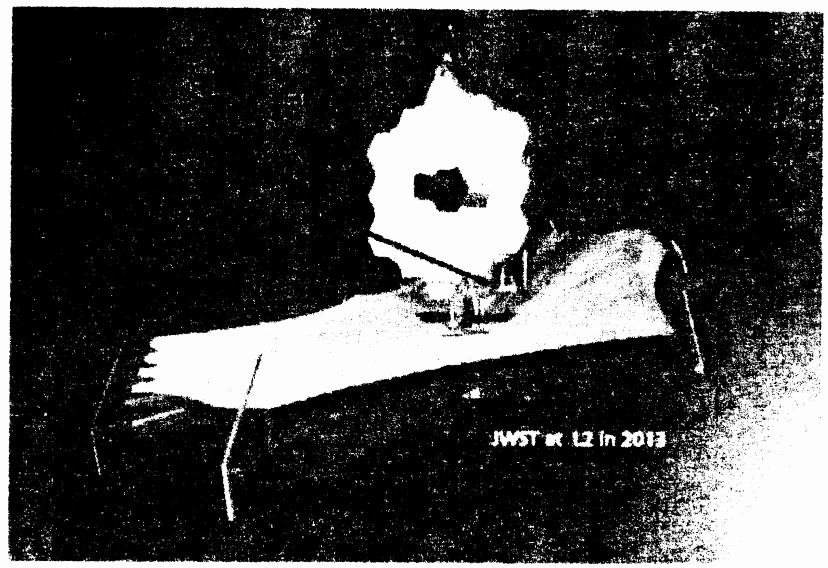
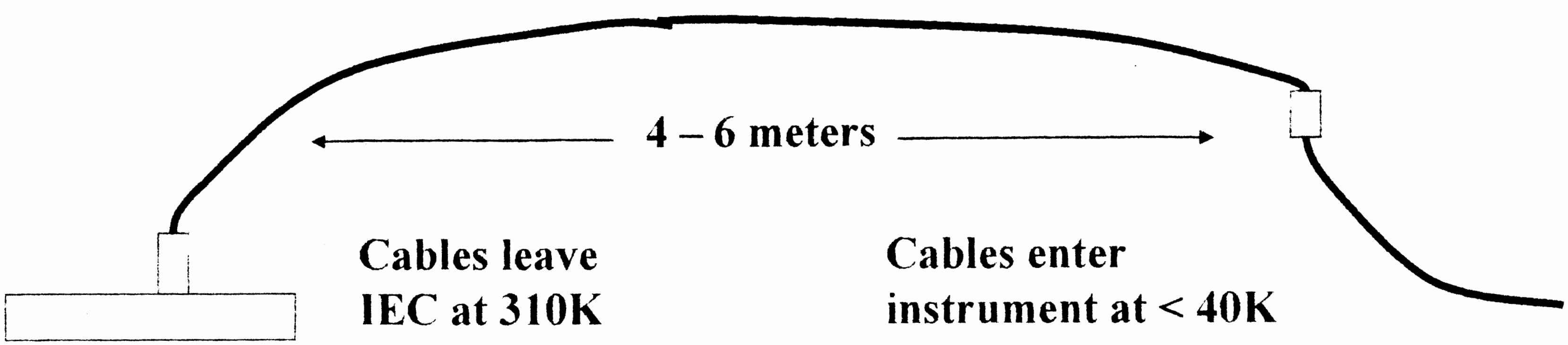


ISIM Harness Test Program

- Background
  - The harness is a thermal path from the warm Instrument Electronics Compartment (IEC) to the cold ISIM. Because of the impact of this load to the ISIM thermal design, understanding the harness parasitic heat gains is critical.
  - Approximately 35% of the total radiator load is due to the harnesses.
- Purpose
  - Allow analyst to correlate thermal models of harnesses with actual test data which will provide us confidence in flight predictions being made for the flight configuration.

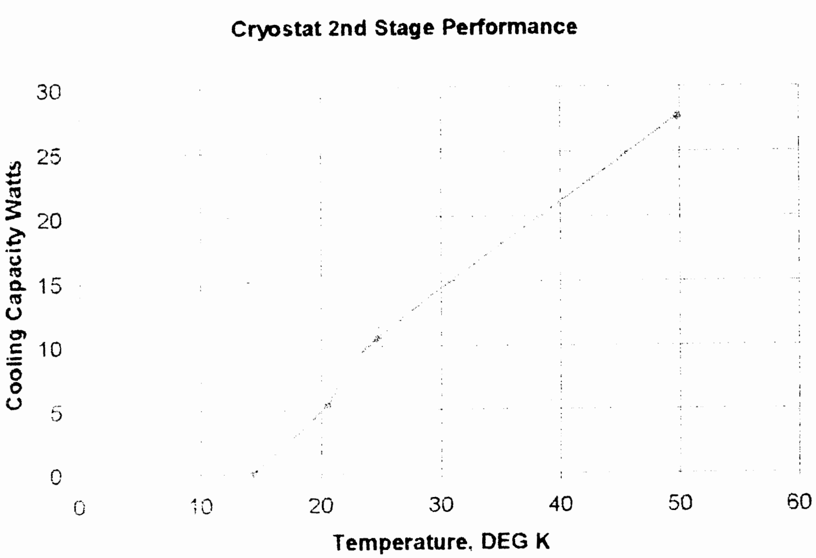


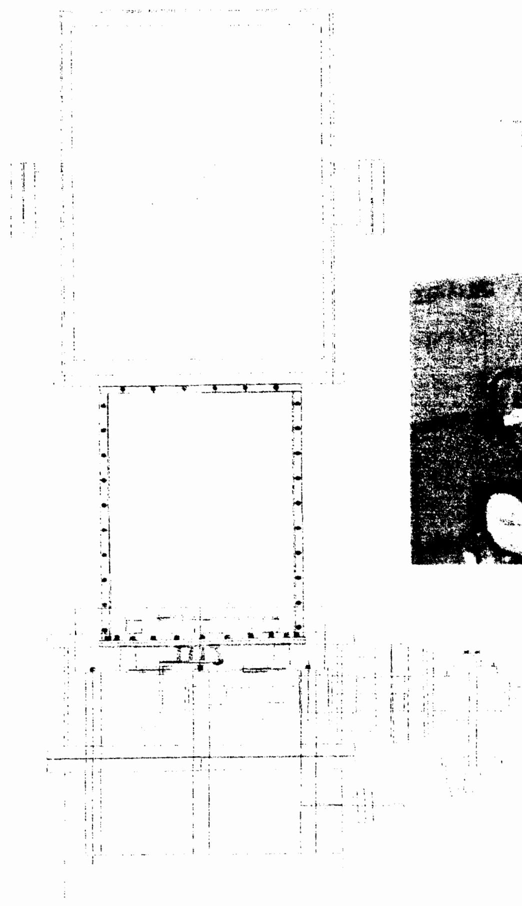
Description of Test Program

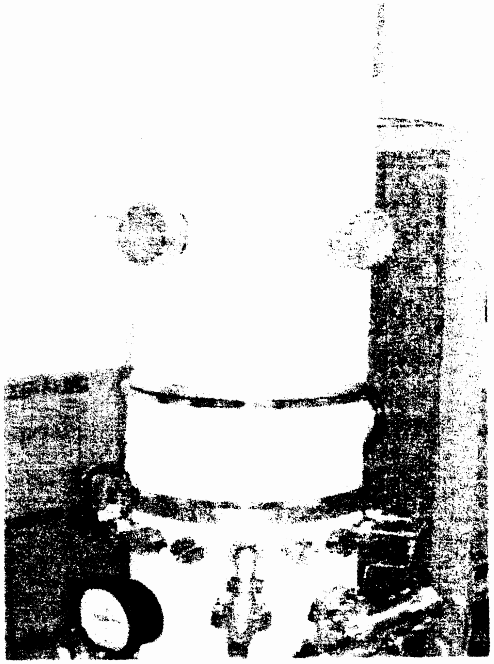
- Rigorous thermal test program is being implemented to quantify each critical analysis parameter. Tests to be performed are:
  - Radial harness conductance when clamped
    - Quantify heat sinking capacity of harness clamp
  - Calibrate heat flow (Q) meter over test temp range
    - A simple device that indicates heat flow as a function of temperature difference measured across the device
  - Linear/axial conduction only of ISIM harness
    - validate with a 304 SS measurement using the same test set up
  - Radial harness conductance when clamped
    - isothermal harness sample, known pressure,

Cryogenic Test Facility
NASA/GSFC Thermal Engineering Branch

- Cryogenically pumped, 18-inch diameter bell jar
- 2 stage GM cryocooler connected to 12 inch dia. by 20 inch tall clamshell
- Provides 20K heat sink for cryogenic testing







Temperature Sensors

- Lakeshore Silicon Diodes
  - Calibrated from 4 to 325K
  - Accuracy,
    - +/-20mK below 100K, +/-30mK above 100 K
- Lakeshore 218 temperature monitor
  - Resolution
    - ~10mK over entire range
- Heat dissipation of sensor
  - 20 microwatts at 4.2K, decreasing with increasing temperature
- Leads
  - 36 gage phosphor bronze, 24 inch typical length
    - heat sunk as required, no copper leads inside clamshell

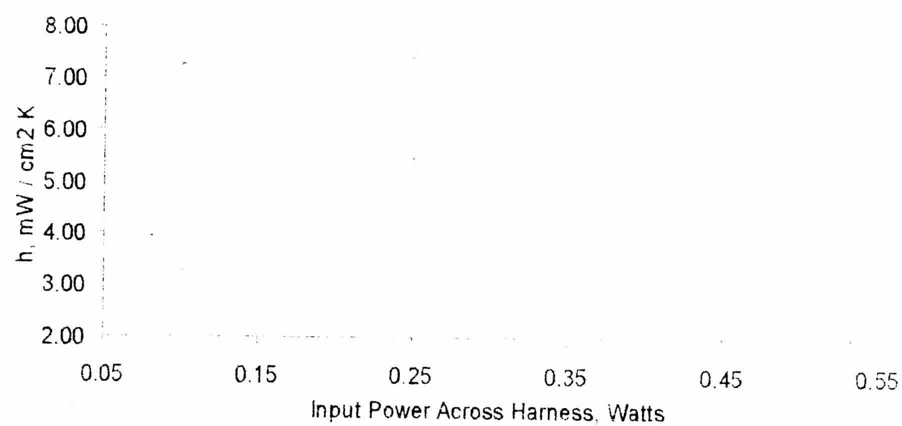
Test Heaters

- Test Article Heaters
  - Design heater circuits for high resistance, low current
    - Eliminates lead resistance concerns, minimizing parasitic heat loads
  - Typical power measurement is 10 to 25 milliwatts
  - Resolution of heater power measurement ~ 50 microwatts
- Leads
  - 4 wire measurements
  - 30 or 36 gage manganin heater leads
  - Calculated heat leak is small ~ 10 microwatts
- Control
  - PID temp control, large time constants lead to long settling times
  - Stability of temperatures is determined by heater control power

Harness Heat Sink Test

- Background
  - Harness clamps are needed every 6 to 8 inches for vibration restraint and harness radiator may be required to reduce parasitics to ISIM interior
- Purpose
  - Quantify through thickness harness conductance
- Method
  - Measure DT across thermally isolated heater plate and controlled sink plate with known Q being applied from one side
- Result
  - Significant heat can be removed from harness with little clamping

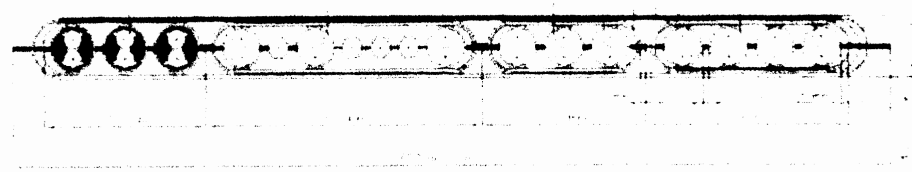
No Indium



ISIM Harness Overview

- Two Types
  - Flat ribbon, Focal Plane Electronics (FPE) type
  - Round bundle, Instrument Control Electronics (ICE) type
- Official Length
  - 4 to 6 meters
  - actual length likely to be shorter
- Operating Temperature Range
  - 310 K to 37K
- FPE Harness (flat ribbon)
  - 30 No. 38 AWG phos bronze wires with teflon insulation
  - 2.6 in. width x 0.19 in. thick
  - 3 layers of kapton/gold shielding

FPE Harness cross section



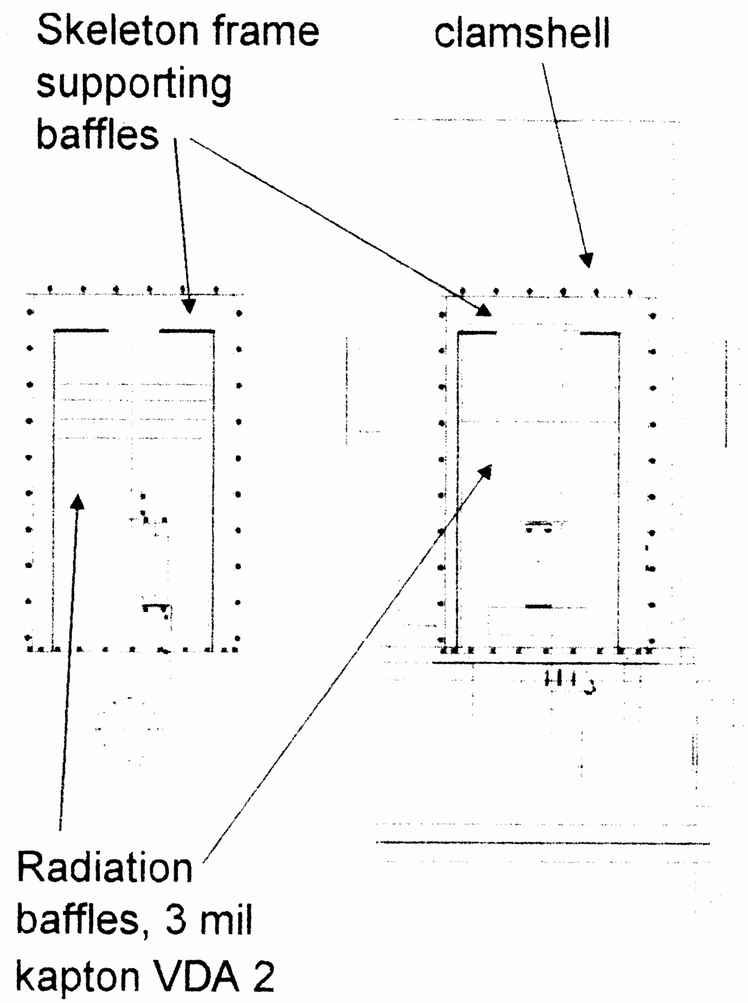
Cold Sink

Heated end, clamp removed

9 inch long test article being assembled into test fixture

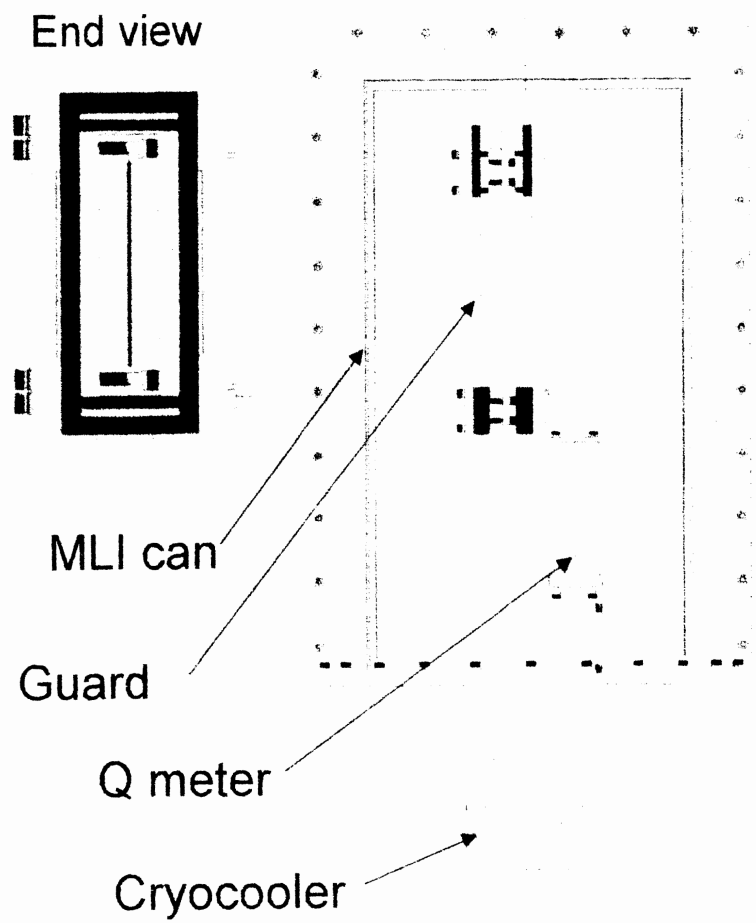
Harness Conduction Only, Baffle Test Set Up

- Objective
  - Minimize radiation losses from the harness to its surroundings
- Approach
  - Use radiation baffles along length
- Test Method
  - Control cold sink temperature and apply known heat to warm end
- Result
  - Heater power required for desired temperature difference was orders of magnitude greater than the prediction indicating problem with radiation baffle test set up



Harness Conduction Only, Guard Test Set Up

- Objective
  - Minimize radiation by matching temperature gradient along harness with a controlled guard
- Approach
  - Design double wall guard surrounding harness, attached to cold sink
  - control warm end to match harness warm end
  - Fill void spaces with fiberfrax insulation to further eliminate radiation effects
    - Fiberfrax is a ceramic fiber insulation with ultra low thermal conductivity



Harness and Guard Test Set Up

Aluminum guard blocks, heaters embedded/epoxied

Warm clamp 2-1.5 Kohm resistors, epoxied

Guard annulus, 304 SS, control sensor to match warm clamp

Warm Clamp, control sensor

Harness and guard midpoint sensors to verify linear gradients

Harness warm and cold end sensors, embedded in harness

Cold clamp control sensor

Fiberfrax Insulation

Cold Sink thermally attached to 1^{st} stage of cryoccoler Clamshell attached to 2^{nd} stage.

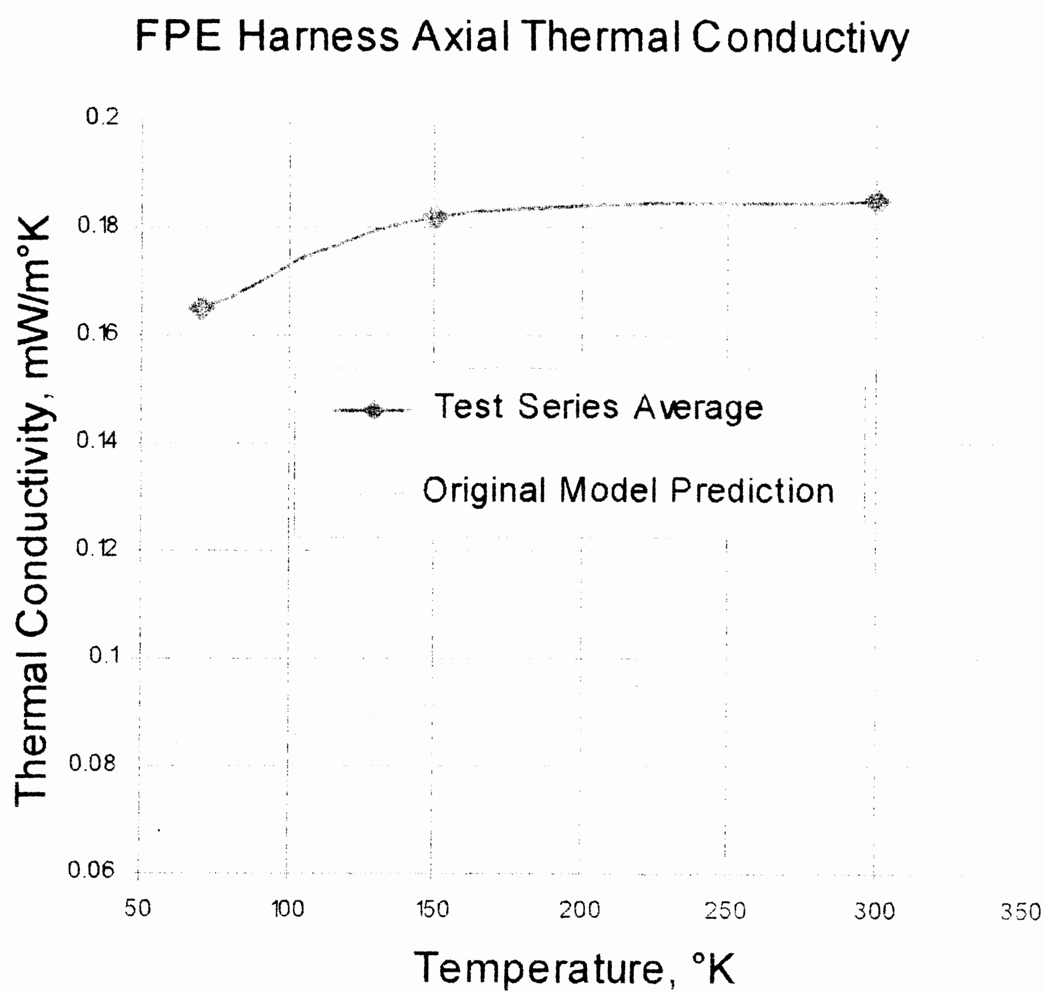
As Performed Test Matrix

- Test Procedure
  - Evacuate chamber, enable cryocooler, set thermal boundary conditions
  - Wait for stability as seen by change in warm clamp power
- Sensitivity tests
  - Decrease guard temp by 0.5K
  - Quantify warm clamp power increase, determines possible effect of thermometry offset
- Plot Delta T verse warm clamp power, slope determines thermal conductance, eliminates parasitics

HarnessTest Matrix			
Constant Average Harness Temperature	Harness Tempeature Difference	Cold Clamp	Clamshell. Warm Clamp and Guard
	Delta T	Set Point	Set Point
300 K			
1A	6K	302 K	308 K
1B	10 K	300 K	310 K
1C	14 K	298 K	312 K
1D	18K	296 K	314 K
1D sensitivity	18K	296 K	314 K
150 K			
3A	6 K	145 K	151 K
3B	8 K	144 K	152 K
3C	10 K	143 K	153 K
3C sensitivity	10 K	143 K	153 K
69.5 K			
2A	4K	67.5 K	71.5 K
2A sensitivity	4K	67.5 K	71.5 K
2B	5 K	67 K	72 K
2C	6 K	66.5 K	73 K

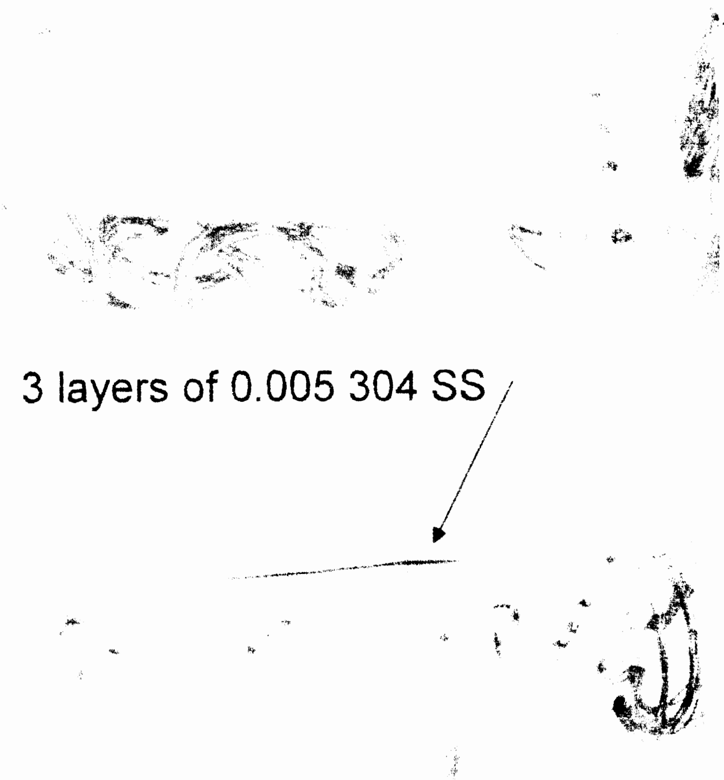
Test Data Results

- Measured thermal conductivity is **two** times expected
  - Big impact to project
- Temperature profile along harness axial is linear
  - Conductivity is near constant for small DT's
- Sensitivity tests
  - Proved small offsets in thermometry are within measurement error, <10%
- Slope of delta T verse applied power were linear
  - Measurement not power dependent



Measurement Verification

- Purpose
  - Determine if any systematic test errors are present to validate harness conductance test results
- Approach
  - Measure thermal conductivity of known 304 SS sample
  - Maintain test set up as close as possible to harness set up
  - Perform same test matrix
- Result
  - measurements <10% off



Lessons Learned, Cryogenic Testing

- Tests were very challenging at cryogenic temperatures
  - sensitivity to milliwatt heat leaks leads to test reconfiguration
- Analytically model every wire, especially heater leads, pretest
  - Determine minimum wire gages for maximum heater currents
- Closeout any small view through MLI to ambient
  - Even very small views to ambient have large influence
- Q meter hinders ability to obtain low sink temperatures
  - Intrinsic temperature difference with Q increases sink base temp.
- Radiation baffles are not effective at eliminating radiation heat transfer to test article as well as difficult to model
- Double wall guard had gradient from inside to outer layer
- Interface conductance of clamps is important for getting heat into material

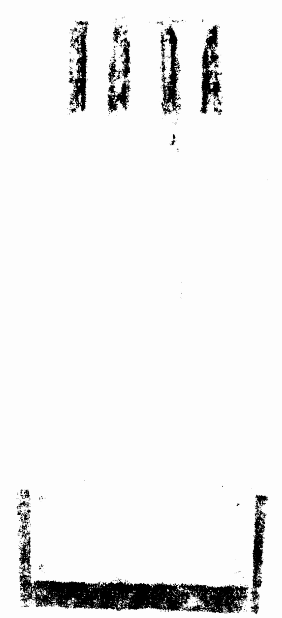
Conclusions

- Harness heat sink conductance tests were encouraging
- Measured conductance of FPE harness is twice the predicted value
  - Implies large impact on heat loads to ISIM and may result in a redesign of FPE harness (Total of 18 FPE harness)
- FPE conductance measurement has been validated with the correlated thermal model for the 304 SS test sample
- Re-enforces the need for a dedicated harness radiator
  - Currently being implemented by the project
- Results clearly demonstrate the importance of testing

What's next ?

- Radial Conduction test will be performed on various ISIM harnesses to determine clamping thermal and electrical effects
  - Using joule heating to simulate internal harness heating
- Test program continues as harness's evolve and requirements mature
  - Larger sections of harness to be tested at system level in larger chamber and in a more flight-like configuration such as the Harness Radiator Breadboard

ICE Harness Test Article being prepared for conduction only test



Acknowledgements

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  - Jim Tuttle GSFC Cryogenics Branch

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    - http://www.jwst.nasa.gov